Answering the Key Questions:
The Latest PM Research Results

Presentation to

California Air Resources Board

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by

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Health Effects Institute

The Health Effects Institute
www.healtheffects.org

- Independent Non-profit Research Institute Since 1980
  - Impartial, high-quality science on health effects of emissions
- Joint and Equal Core Funding
  - Government (U.S. EPA)
  - Industry (28 Worldwide Vehicle Manufacturers)
  - also other agencies and industries
- Independent Board and Expert Science Committees
  - oversee and review competitively-selected research
- Over 200 studies
  - particulate matter, ozone, carbon monoxide, diesel exhaust, benzene, butadiene, methanol, others

The Data We Had in 1997
Short Term Epidemiology

- Daily variation in PM and health
- Some 40 studies in Europe (APHEA) and U.S.
- Consistent small increase in mortality, hospitalization: 0.5-1.0%/10 micrograms

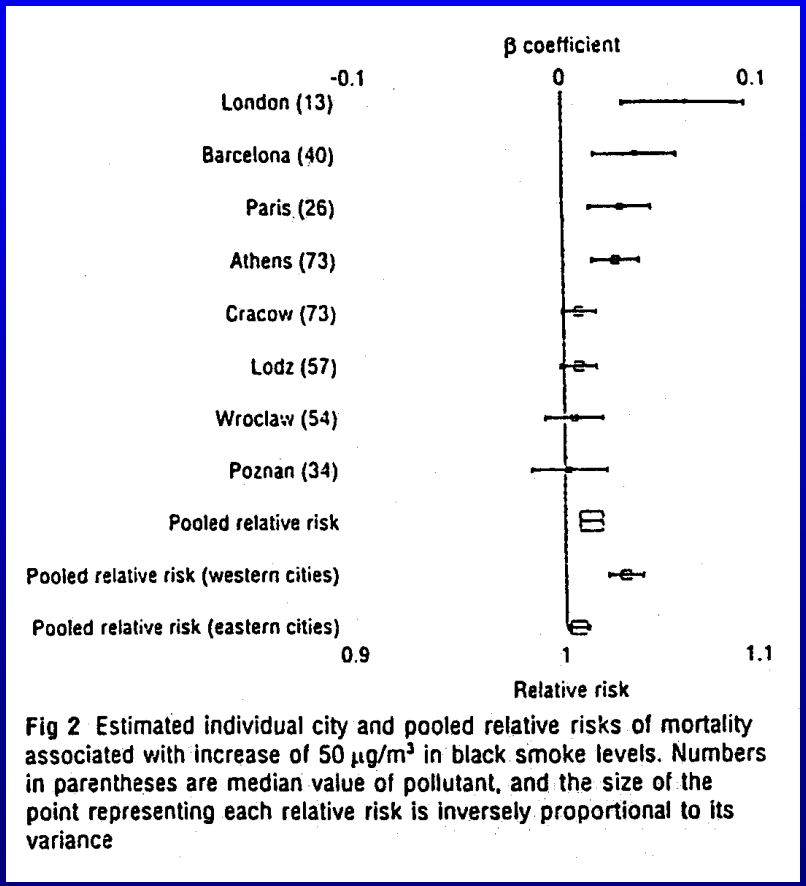
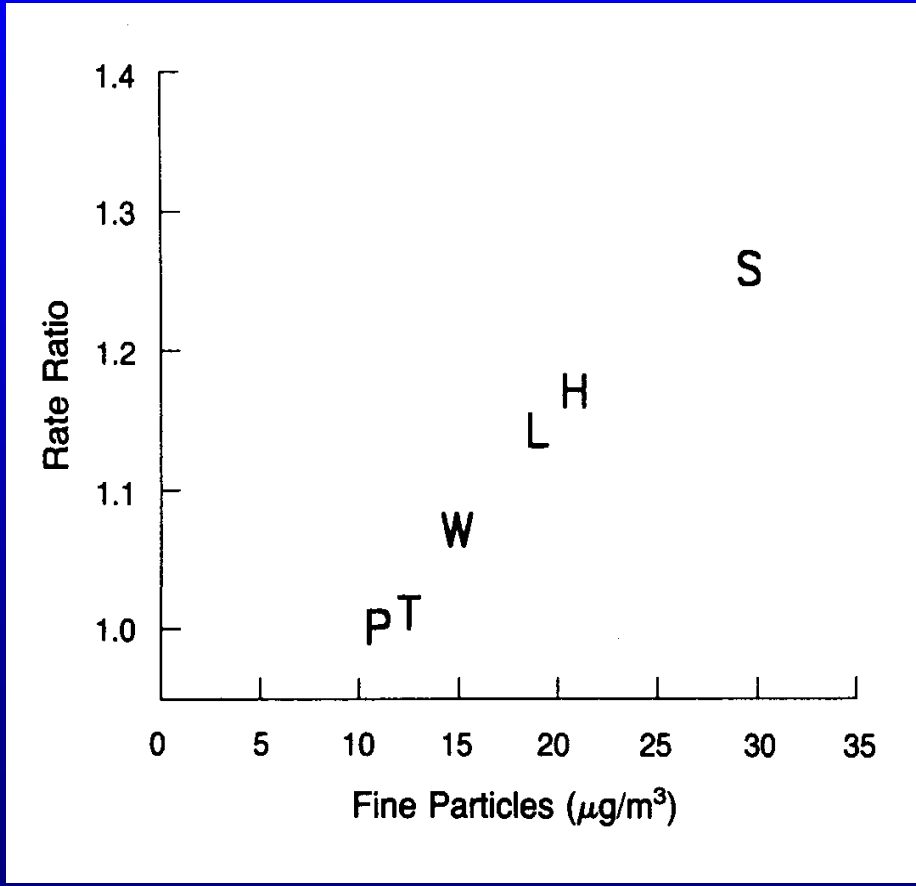


Fig 2 Estimated individual city and pooled relative risks of mortality associated with increase of 50 μg/m³ in black smoke levels. Numbers in parentheses are median value of pollutant, and the size of the point representing each relative risk is inversely proportional to its variance

The Data We Had in 1997

Long Term Epidemiology

- Longer-term PM exposure and mortality
- A few studies in U.S.
  - Harvard 6 cities
  - Pope/ACS
- Larger effects:
  - 4.0 - 5.0% / 10 micrograms

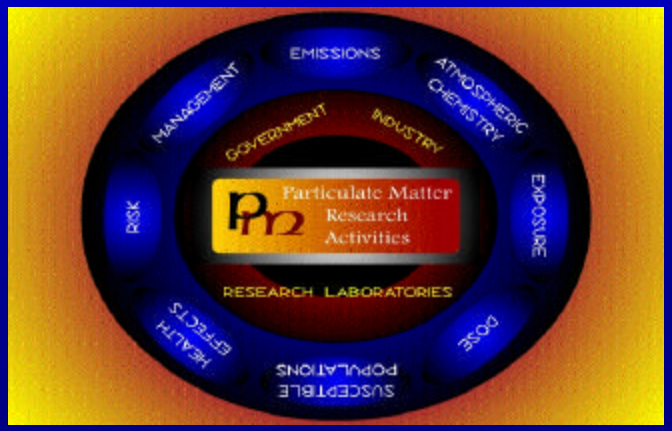


The Key Questions

- Strength of the Epidemiology
  - Consistency across cities?
  - Role of other pollutants?
  - Exposure
  - Strength of 2 Major Long-term Studies?
- The Importance of Different PM Components
  - Are all particles created equal? Are some sources more or less toxic?
  - What is the best metric for regulation?
- Mechanisms of Effect?

Answering the Key Questions

- Much Research Underway: EPA, CARB, HEI, EPRI, Canada, Europe, Others
- Over 500 Projects Described Online
  - www.pmra.org - HEI Worldwide PM Research Inventory:

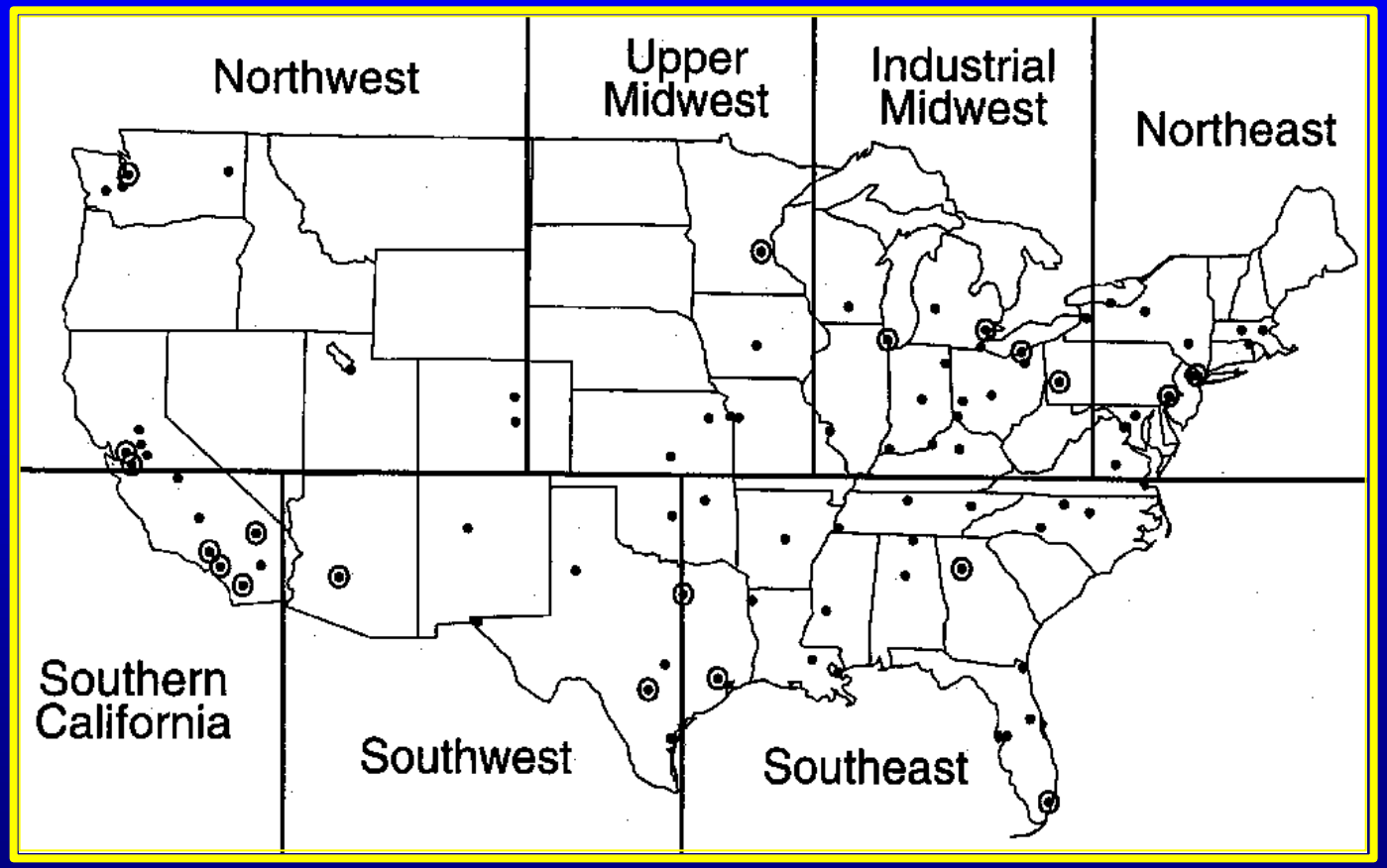


- Some Results Now In; Additional Answers over Next Two Years

Strength of the Epidemiology
Short Term

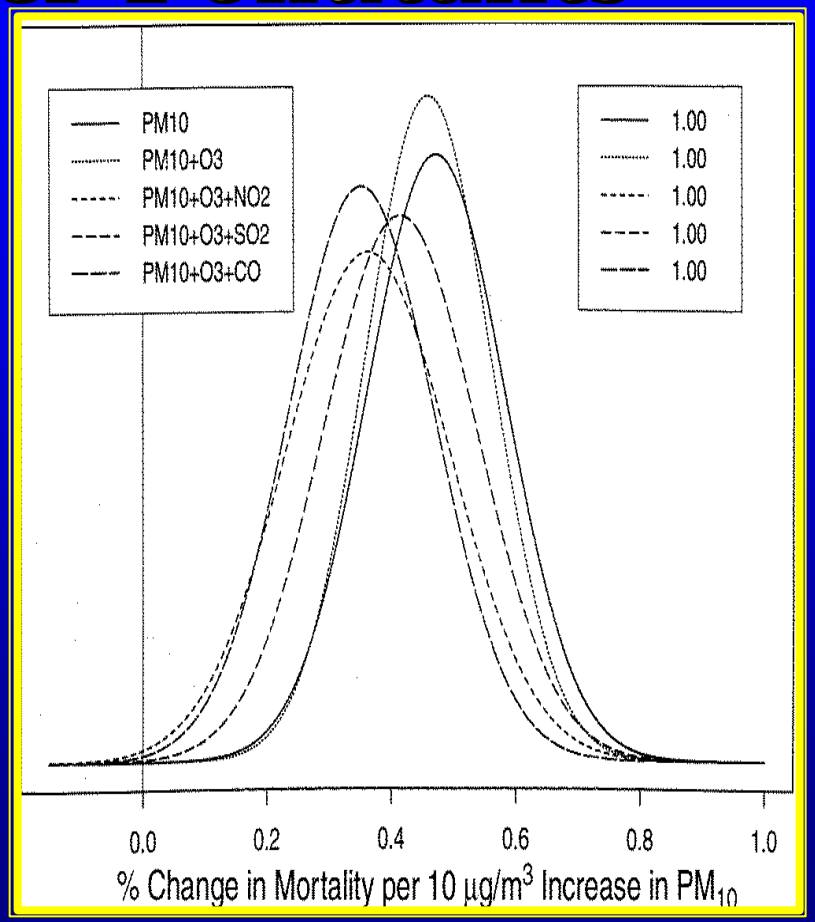
- National Morbidity, Mortality, and Air Pollution Study (NMMAPS)
  - HEI-Funded, Team led by Johns Hopkins University
- Systematic Analysis in 90 largest US cities
  - Air Pollution
  - Mortality
  - Weather
- Similar Analysis of Elderly Hospitalization in 14 US Cities

NMMAPS - 90 Largest US Cities

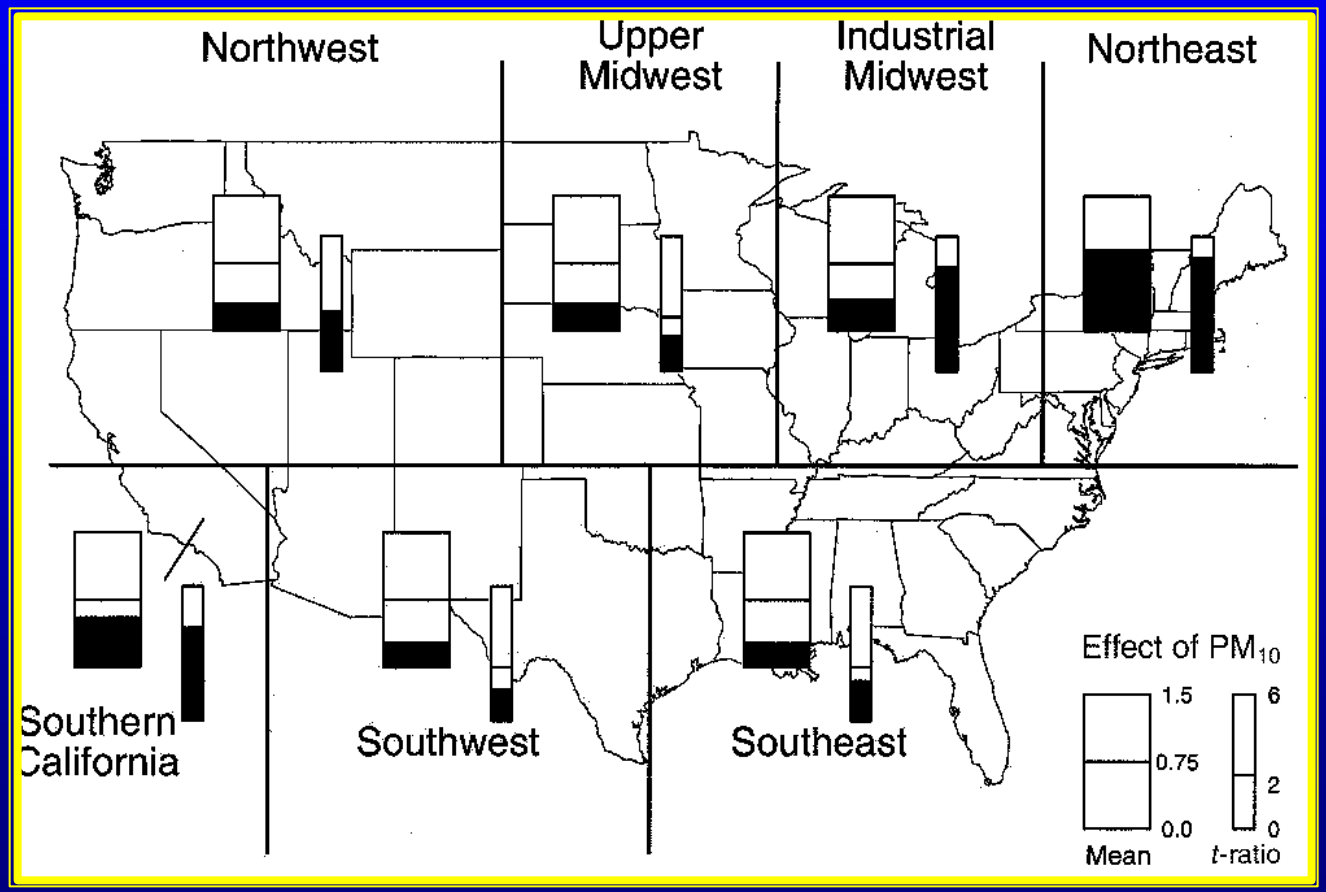


NMMAPS
The Role of Other Pollutants

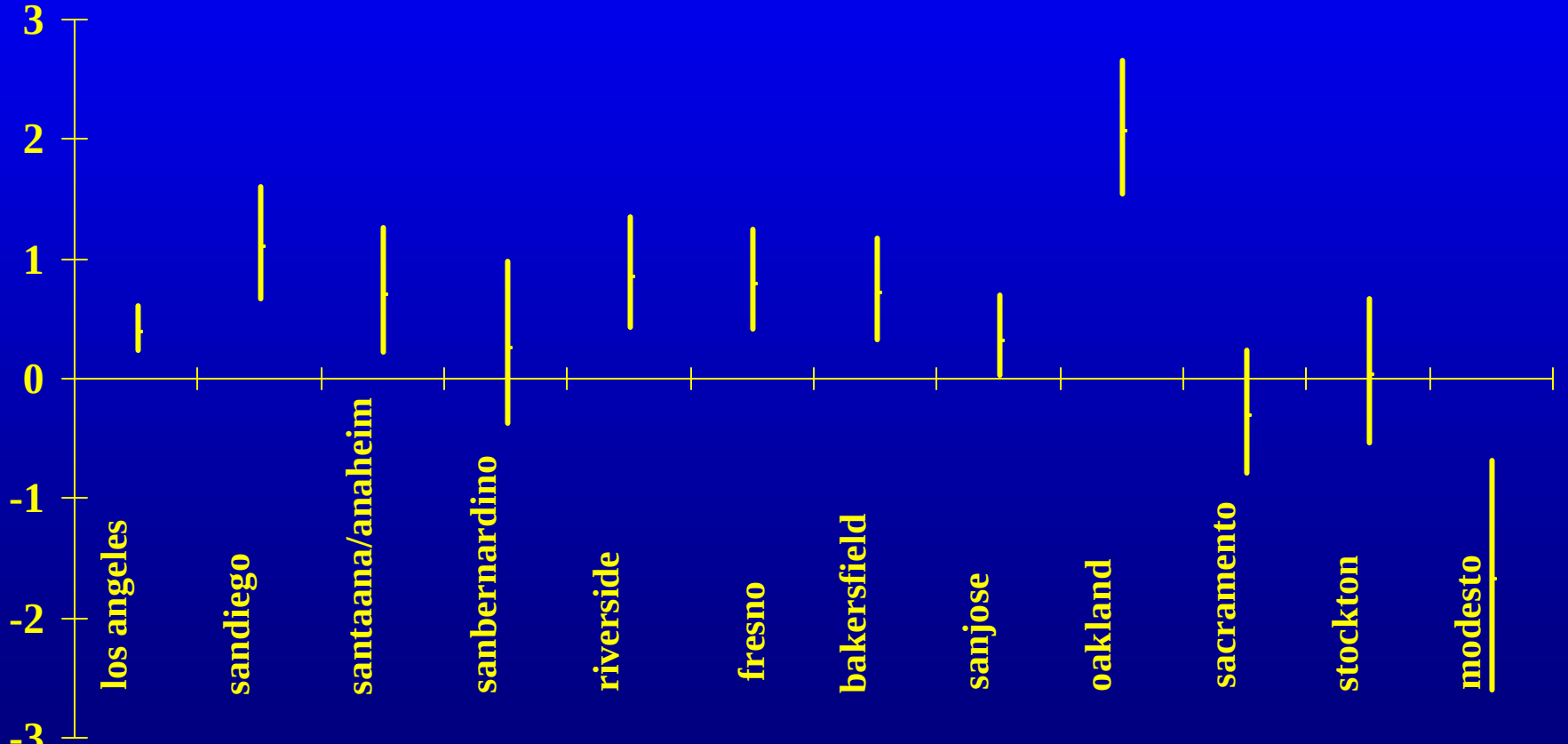
- Relatively Consistent Increase in Mortality:
  - 0.5% per 10 u/m^3 of PM10
- About half the magnitude of previous U.S. analyses
- Apparently not sensitive to inclusion of other pollutants
- Harvesting? Some deaths appear to be advanced more than a few days
- Exposure errors? Not likely to change results
- *Overall*: Greater confidence in results



NMMAPS
Regional Effects of PM10



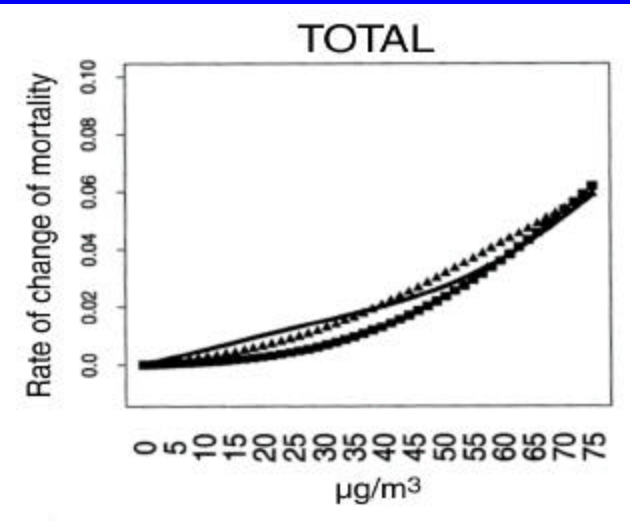
NMMAPS - California Results
% Change in Mortality per 10 ug/m3

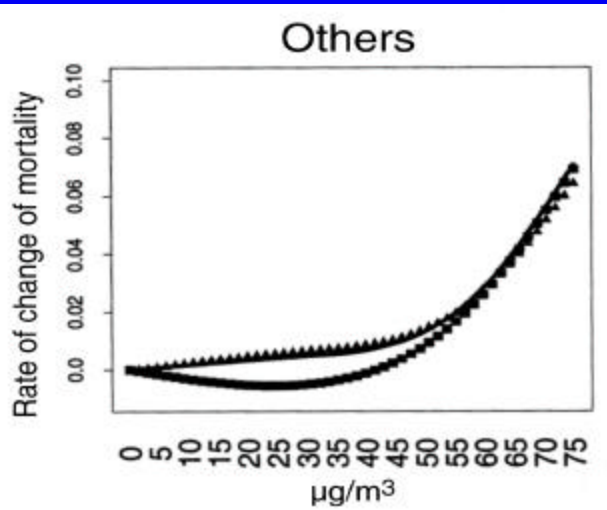


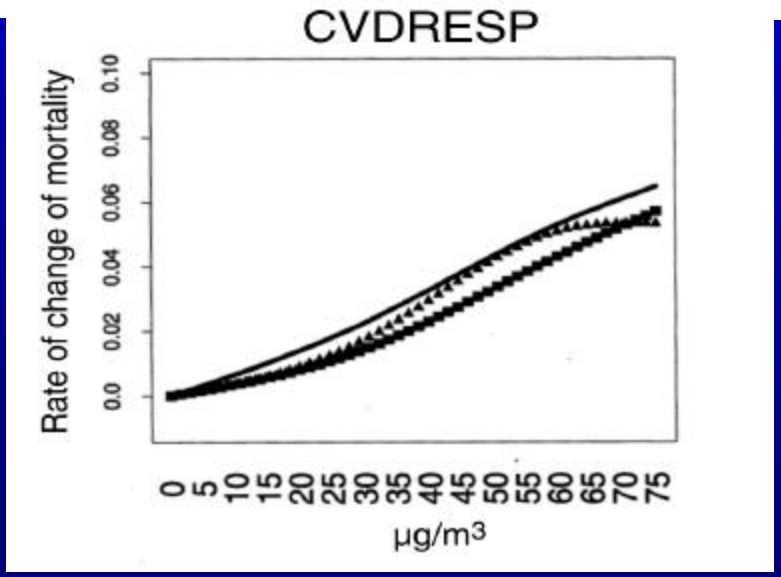
NMMAPS

Exposure - Response for the 20 Largest US Cities

(Daniels et al AJE 9/1/00)







Strength of the Epidemiology
Long term

- Harvard Six Cities and American Cancer Society Studies
  - Only Major Studies of Long Term Effects in 1997
- Basis of all PM benefit and cost analysis:
  - US EPA Estimate (1997) - 15,000 deaths
  - WHO Estimate (Kunzli et al, *Lancet* 2000) - 40,000 deaths attributable to air pollution in FR, AUS, SWITZ
- HEI asked to conduct in-depth reanalysis by all parties
  - Expert Panel picked team from U. Ottawa to conduct Reanalysis

Extensive Analysis

- ***Accurately Done?*** Audit tested 500 individual files
- ***Replicable?*** Team did detailed duplicate analyses
- ***Analytic Approaches?*** Over a dozen different models
- ***Individual differences?*** Nearly 30 new individual variables
- ***City Differences?***
  - Assessed effect of 20 ecologic variables (including income, health care, altitude, water hardness, other pollutants)
  - Applied new analytic techniques to assess spatial patterns

Reanalysis Results

- **Overall,**
  - **Assured the quality of the data**
  - **Replicated the original results, and**
  - **Tested those results against alternative risk models and analytical approaches…**
  - ***... without substantively altering the original findings of an association between indicators of particles and mortality***

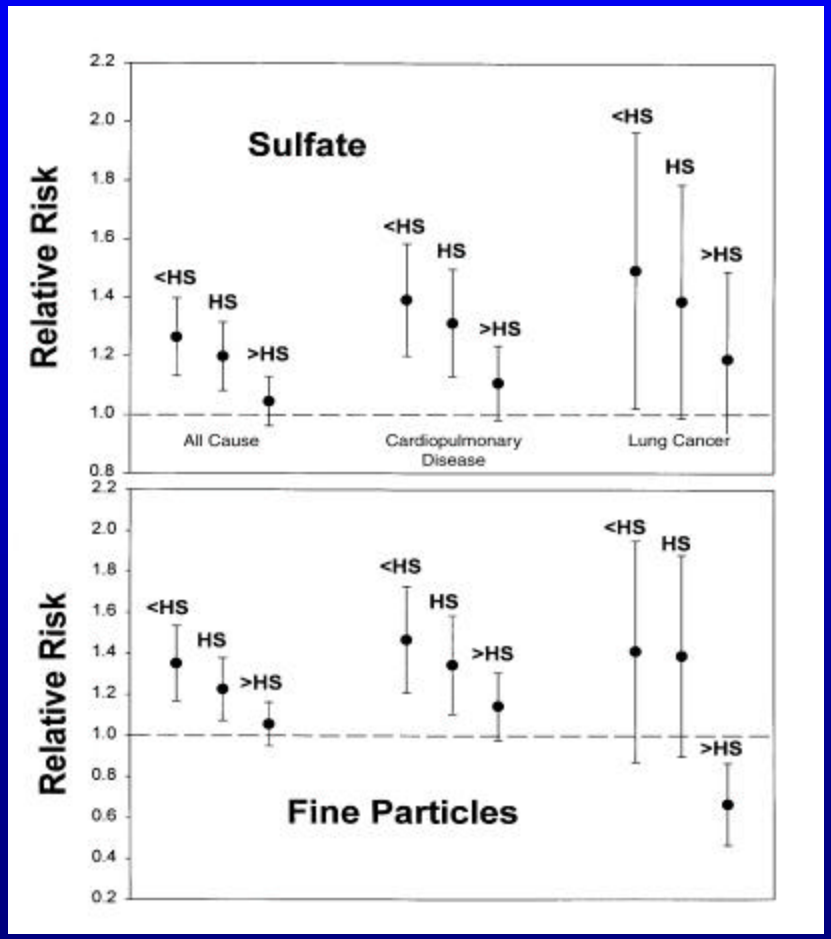
Relative Risks (ACS)

- **Comparing most to least polluted cities**
- **With additional personal data**

Analysis	*PM2.5*	*Sulfates*
Original	1.**17**(1.08,1.27)	1.**15**(1.08,1.22)
Full	1.**18**(1.09,1.26)	1.**15**(1.09,1.21)
Extended	1.**18**(1.09,1.26)	1.**15**(1.09,1.21)

Reanalysis Results : Education

- Risk increases with lower education
- Education a surrogate for social class
- Due to
  - differences in true exposure?
  - sensitivity to air pollution?



Reanalysis Results: Spatial Analyses

- New Techniques applied to consider correlations among cities near one another:
  - the effects of fine particles remained but were diminished
  - Association between sulfur dioxide and mortality was also observed
    - **persisted when other variables were included**

Reanalysis Conclusion

- The Reanalysis:
  - identified relatively robust associations of mortality with fine particles, sulfate, and sulfur dioxide, and
  - tested those associations in nearly every possible manner within the limitations of the data sets.
  - "*mortality may be attributed to more than one component of the complex mix of ambient air pollutants in urban areas*"

Answering the Key Questions
Relative Importance of PM Components

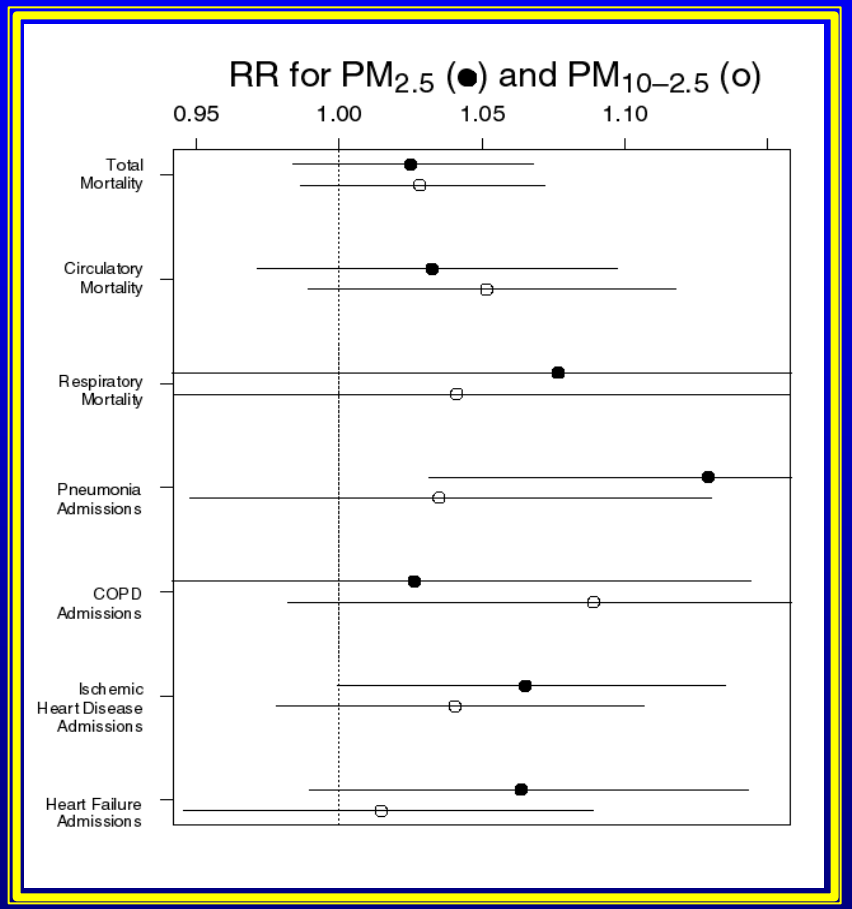
- Are all particles created equal?
  - Are some more toxic than others?
  - Are some sources of more concern (e.g. diesel, power plants, certain industries, others?)
  - What is the best metric for regulation?
- Many studies underway testing different components, characteristics
- Initial results beginning to come in

The Major Health Hypotheses

- PM mass
- PM particle size, surface area
- Ultra fine PM
- Reactive transition metals
- Acids
- Organic compounds
- Biogenic particles
- Sulfates and nitrates
- Peroxides
- Soot (e.g.elemental carbon)
- Co-pollutants - SO2, CO, etc.

PM Components
Initial Results: Studies Underway

- New HEI PM size studies:
  - Erfurt: UFs, PM10, 2.5
  - Detroit - PM10, 2.5
  - Rochester - UF inflammation
- To date:
  - Similar effects for PM10, 10-2.5, 2.5, UF
- Studies underway on metals (e.g. iron), PAHs, others



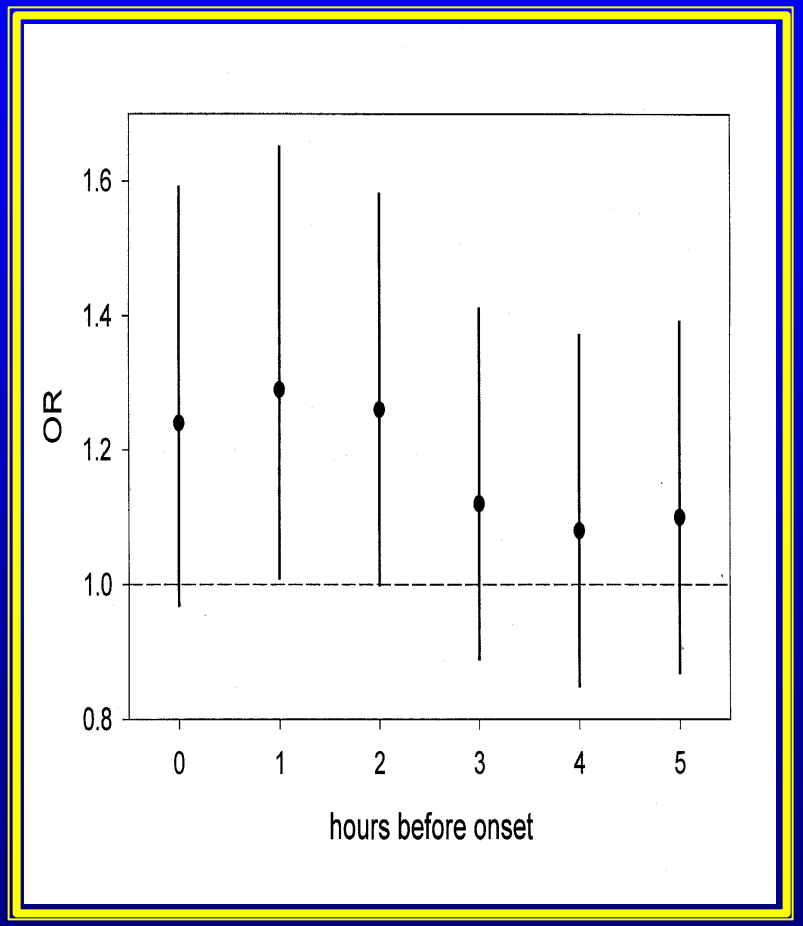
Answering the Questions
Mechanisms

- What biologically plausible mechanism could explain results?
- A number of hypotheses
  - effects on the lungs or heart
  - a combination of effects
- Animal, epidemiology and human studies underway: some initial results
- Still early in our understanding

PM and Heart Attack Onset

Peters et al. Circulation June 2001

- Case-crossover study of 772 Boston MI patients
- Hourly $PM_{2.5}$, EC, and gaseous pollutants
- Strongest associations with $PM_{2.5}$ prior to onset at:
  - 2 hr (25 $\mu g/m^3$) RR=1.48,
  - 1 day (20 $\mu g/m^3$) RR=1.69



Looking Ahead

- We know more than in 1997
  - short and long term epidemiology relatively robust; some questions remain
  - Associations of PM and mortality smaller than previously estimated
  - Initial exposure studies: exposure differences not likely to change results
  - May be mortality effects from the mix of combustion pollutants (e.g. PM *and* SO2 or other correlated pollutants)

Looking Ahead

- We are still learning
  - regional differences need more explanation
  - beginning to test comparative toxicity of different sizes, components, and sources of PM
  - early stages of testing mechanistic hypotheses
- Knowledge likely to grow
  - In short term - better personal exposure data coming in
  - Over longer term (5 - 7 years) - better source toxicity data to inform any future standards and control programs